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World's First Delta Wing Airplane Convair/Air Force XF-92A

William F. Chana
San Diego Aerospace Museum

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ABSTRACT

The first flight of a delta wing airplane took place in the United States at the Muroc AFB Flight Test Center on 18 September 1948. The airplane, Convair No. 7002, Air Force S/N 46-682 and designated the XF-92A was piloted by Convair's Manager of Flight Research, E.D. "Sam" Shannon. The author witnessed this historic flight as a Flight Test Engineer on the project.

Studies and wind tunnel tests for a supersonic interceptor were conducted at the Vultee Division of Consolidated Vultee Aircraft Corporation (Convair) in 1945. These studies led to the selection of the 60° delta wing plan form. This paper reviews the major differences between the thin wing XF-92A and the thick wing DM-1 glider (never flown) designed by Alexander M. Lippisch in Germany at the close of World War II.

The XF-92A used a fully hydraulic irreversible control system for its elevons and rudder. The only airplanes up to this time with fully hydraulic controls were the Northrop XB-35 and the YB-49 flying wings. The flights of the XF-92A flown by Convair test pilots, Shannon and Bill Martin are compared to the flights flown by Air Force test pilots, Capt. Chuck Yeager and Col. Pete Everest.

The historic XF-92A has been fully restored by the U.S. Air Force Museum in Dayton, Ohio. It will be on display for the world to see this one airplane that pioneered the development of the delta wing proving its worth as an efficient aerodynamic shape for transonic and supersonic flight.

INTRODUCTION

The delta wing concept was created at the Consolidated Vultee plant in Downey, California. The Air Force wanted a supersonic interceptor and Vultee engineers won a study contract. The designers first laid out a highly swept narrow cord wing. Wind tunnel tests of this design indicated that it had unacceptable stability and control characteristics. Ralph H. Shick, a Vultee aerodynamicist, offered a suggestion to Adolph Burstein, Chief Technologist, and Frank Davis, test pilot and head of Aero and flight test. Ralph said, "Why don't we just fill in the area between the two wing tips? (Fig. 1). This will give us more wing area, more room for fuel, a thinner wing and a pure three-pointed delta.

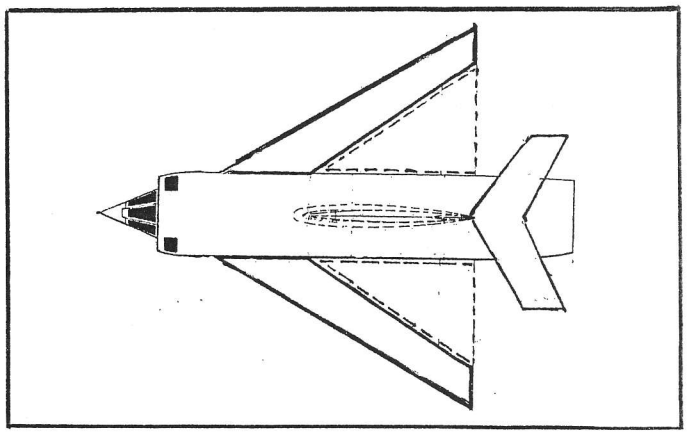

Figure 1 Fill in area between wing tips & eliminate Horizontal Tail Creates Delta Wing Plan Form

Ralph's suggestion was accepted and the wing tunnel results showed great promise for this new wing plan form.

In Germany, Alexander Lippisch had done work during WWII on highly swept wings and near the end of the war had constructed a wooden delta wing glider (Fig. 2). The glider, identified as the DM-1, never flew. After the war it was brought to the U.S. and was tested in the NACA Langley full scale wind tunnel. It is in storage at the Smithsonian National Air and Space Museum. After the Vultee team selected the delta plan form, Shick met with Dr. Lippisch at Wright Field to discuss their work and Lippisch was in agreement with the Convair concept.

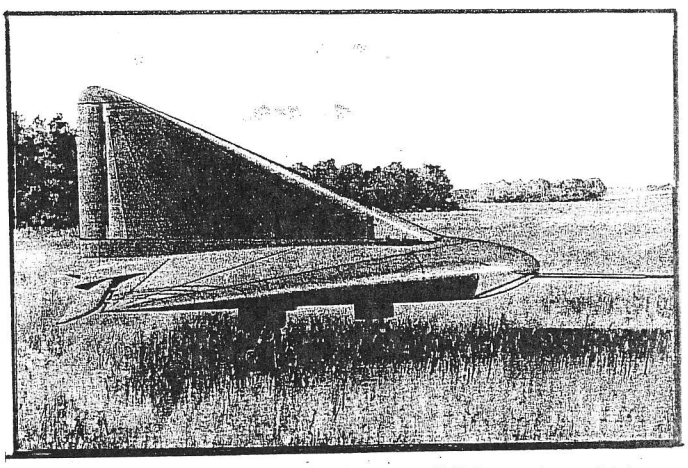

Figure 2 Alexander Lippisch post WWII wooden glider

*1996-1998 President, San Diego Aerospace Museum, AIAA FELLOW, SAE FELLOW, XF-92A Flight Test Engineer - GD Convair (Retired). Copyright 2000 by William F. Chana, Published by SAE International, and the American Institute of Aeronautics and Astronautics, Incorporated with permission.

Convair was given the go-ahead to develop a Mach 1.7 interceptor using the delta wing. The Air Force identified the proposed interceptor as the P-92 (Fig. 3). It had a 60° leading edge swept wing and vertical tail with a 6.5% thick symmetrical airfoil. A full scale wooden mockup was built (Fig. 4) The interceptor had a circular fuselage and was to be ram jet powered with the pilot seated in the nose spike. Sixteen rocket engines inside the ram jet combustion chamber provided initial thrust and served as flame holders for operation of the ram jet. This late 1940s aircraft would use a rocket powered cart for takeoff, two underwing fuel tanks would be jettisoned when their fuel was expended, and an energy descent to a landing would be made. The landing itself would be made on a tricycle gear designed for landings only. This is the way the U.S. space shuttle operates today.

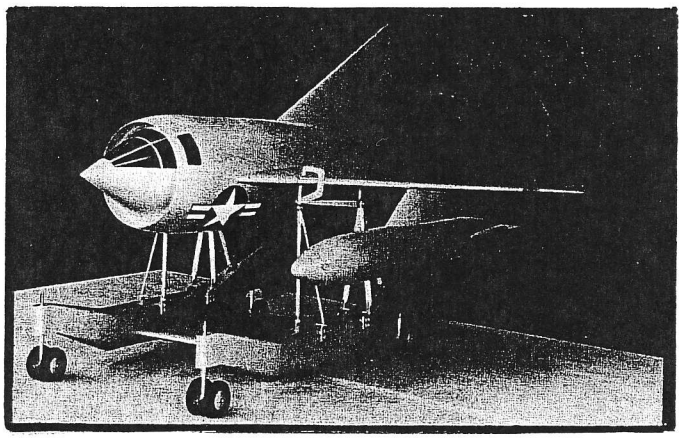

Figure 3 Model of P-92 on Rocket Powered Cart For Takeoff

There couldn't have been a more advanced propulsion system, but it turned out to be the downfall of the P-92. Convair and the Air Force realized that this radical propulsion system was far beyond the state-of-the-art and it could not be developed in time for the interceptor the Air Force wanted.

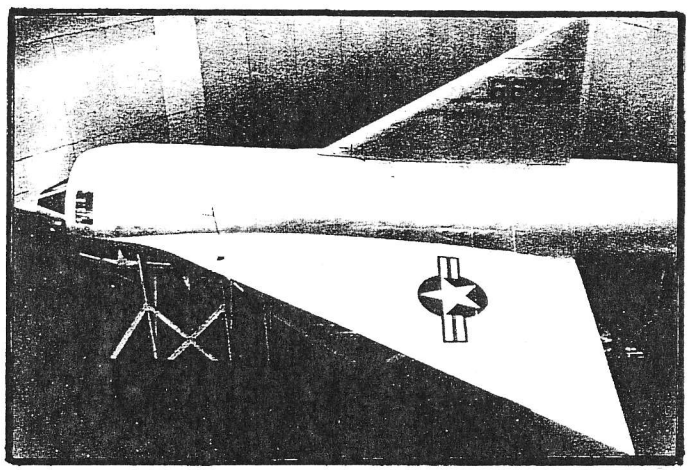

Figure 4 Mockup - P-92 Mach 1.7 Air Force Interceptor

THE FLYING MOCKUP

A contract was given to Convair to build a flying mockup of a delta wing with the 6.5% wing thickness to prove that a delta wing airplane could be

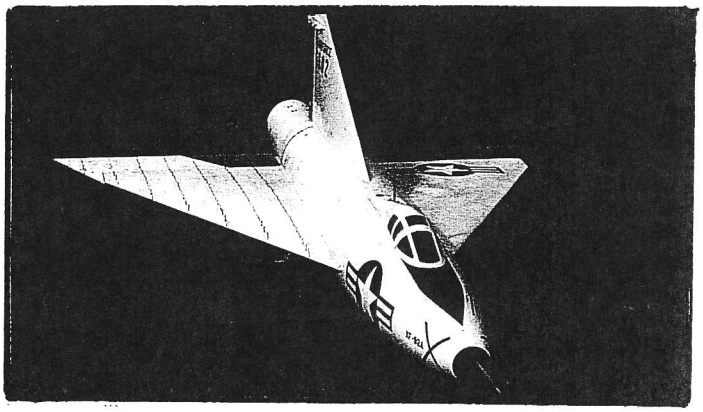

Figure 5 Flying Mockup - CV 7002/ U.S.A.F. XF-92A

flown (Fig. 5). This flying mockup was initially known by Convair number 7002. When the P-92 was canceled the 7002 was redesignated the XF-92A. Frank Davis, Adolph Burstein and Ralph Shick were awarded the AIAA National Aircraft Design Award in 1981 for their major contribution in developing the world's first delta wing airplane (Fig. 6). This

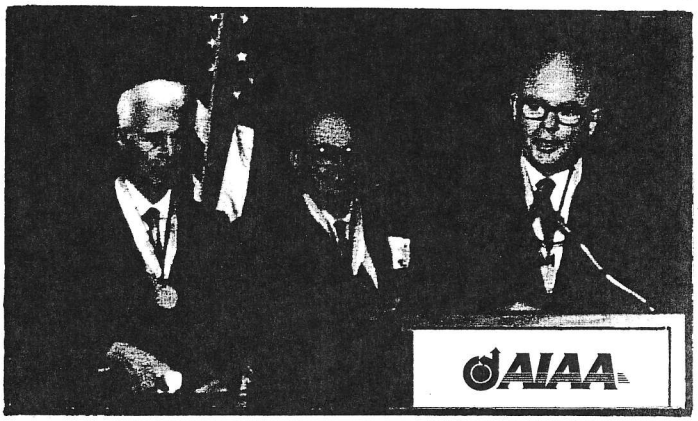

Figure 6 Shick, Burstein, Davis Aircraft Design Awardees

wing plan form is used today on modern fighters and was the wing form selected for the world's first supersonic transport - the Concorde (Fig. 7). The delta wing has good stability and control characteristics and it has low drag penetrating the sound barrier. The wing will not stall up to 40° angle of attack, but drag is high at low speed and high angles of attack.

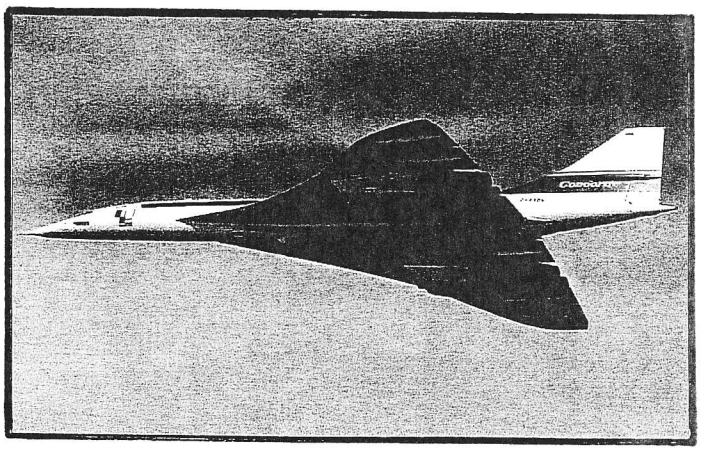

Figure 7 British/French Concorde - Mach 2.2 Delta Wing

Models of the 7002 were tested in a low speed wind tunnel, a free flight tunnel and a spin tunnel. These small model tests gave the engineers confidence that the delta wing could fly and that it would be controllable in flight from low to high angles of attack. In the free flight tunnel the model had "bang-bang" control of the elevons for pitch and roll. Movies of these tests left the impression that the airplane was unstable because the controller (pilot) could not apply smooth linear motion to the elevons. The model wobbled.

Construction of the 7002 was started at the Vultee Field plant in Downey, California. When 75% completed it was moved to the Convair experimental shop in San Diego. Upon its completion, the ship was transported by barge to Moffett Field, California, to be tested in the NACA Ames 40 x 80 foot wind tunnel (Fig. 8). Strip-tube tapes were installed in the wing to measure upper and lower surface pressures. These tunnel tests confirmed what was learned with the small models. The 7002 delta wing was a stable platform and it could fly like any other airplane.

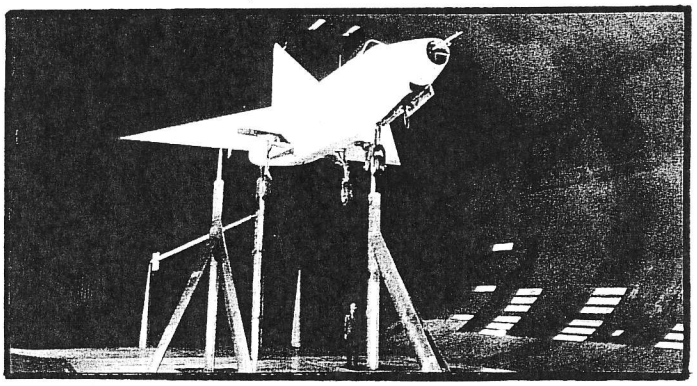

Figure 8 CV 7002/USAF XF-92A in NACA 40'x80' wind Tunnel

Following wind tunnel tests at Ames, the 7002 was returned to the experimental shop in San Diego for engine installation and its final checkout prior to being shipped over land to the Air Force Flight Test Center at Muroc AFB. At Muroc AFB the airplane was assigned to a wooden hangar that was only 40'x40'. The hangar was located on the eastern side of the South base and just a few hundred yards from the edge of the dry lake bed. It was a very old hangar. The 31'4" wing span of the 7002 just cleared the hangar door opening. No one would ever suspect that a secret delta wing airplane was in this old beat-up hangar.

HYDRAULIC FLIGHT CONTROLS

The 7002 had elevons at the trailing edges of the delta wing and a rudder at the rear of a large vertical fin. The left and right elevons moved together for pitch control and differentially for roll control. The elevons and rudder were moved by hydraulic actuators. The airplane employed a single 3,000 psi, hydraulically powered, irreversible flight control system. This experimental airplane did not have a ram air turbine (RAT) that could be deployed into the slipstream to maintain hydraulic pressure if the jet engine or the engine driven hydraulic pump failed. The RAT would be used later in Convair's F102 and F106 airplanes.

Irreversible hydraulic controls were a new innovation in the post war period. The first airplane to use this type of flight control system was the Northrop XB-35 flying wing. Other airplanes by then were using hydraulic boost systems, like power steering in automobiles, but the XB-35, YB-49 (Fig. 9) and 7002 were first to use this irreversible system where control surface hinge moments do not transmit back to the pilot's stick and rudder pedals.

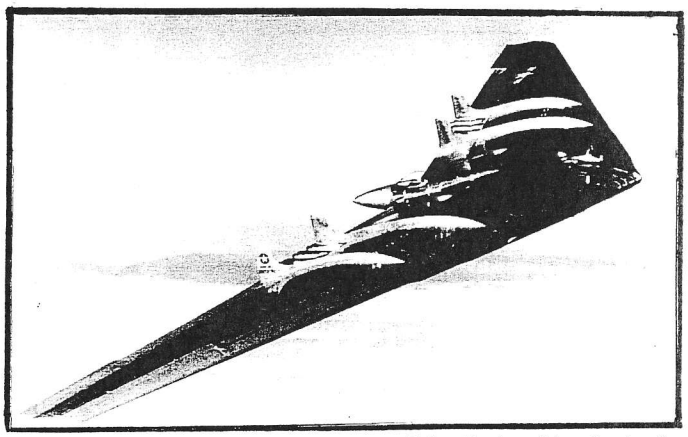

Figure 9 Northrup YB-49 Irreversible Hydraulic Controls

The 7002 had three trim switches and three artificial feel switches. The pilot could move the control surfaces to any desired trim position. There were no trim tabs. The three feel switches allowed the pilot to select the amount of force it took to move the controls away from trim. With full "less" feel it took zero stick or rudder force to move the flight controls through their full travel. With full "more" feel the forces exceeded the pilot's ability to move the controls more than a few degrees from the trim position. This full range of artificial feel allowed the pilot to select the amount of feel that was most comfortable to him and to do so in flight at his own discretion. The airplane did not have a "Q-pot" to automatically change longitudinal feel with airspeed. Convair's F-102 and F106 interceptors incorporated a "Q-Pot".

For a ground demonstration of the flight control system you could select a feel setting that would allow you to move the stick easily through its full travel. As the stick was moved rapidly to any position in the cockpit, the elevons would move rapidly to their respective position with no apparent lag. This was also true of rudder pedal and rudder motion. This provided an impressive demonstration, but it is not the way an airplane is normally flown.

With a conventional cable flight control system, making small changes in altitude and shallow banked turns, takes only slight pressure or a very small motion of the stick. At small displacements of the stick, equivalent to less than one tenth of a degree of elevon travel, the 7002 control system had a dead spot, breakout lag, hysteresis and friction. The elevons did not follow stick position at very small stick displacements.

As an example, if you were flying the 7002 straight and level and wanted to raise the nose a small

amount you would apply a small amount of back pressure to the stick. But instead of both elevons moving up equally only one elevon might move up less than one tenth of a degree. This would then place the airplane in a slight climbing turn. Applying pressure to the stick to correct this condition might cause both elevons to move down equally. In other words, the elevons were not doing what the pilot wanted them to do. With your hand on the stick, the airplane was pitching and rolling in small amplitudes giving the impression that it was aerodynamically unstable. Removing your hand from the stick would immediately stop the airplane's small pitching and rolling gyrations.

SHANNON AND MARTIN - CONVAIR PILOTS

After several high speed taxi runs up and down the lake bed runway, Sam Shannon lifted the XF-92A into the air for its first flight on 18 September 1948 beginning the Phase I test program. As he stepped on the ladder to enter the cockpit he said: "If you see me heading that way and going out of sight, you'll know I can't steer the thing." Sam was a seasoned bomber pilot, an excellent bomber test pilot, and he knew what it took to correct any flying deficiency. However, he flew the XF-92A like a bomber. He made long drawn out landing approaches, no complete barrel rolls, and no fighter maneuvers.

Sam had difficulty flying the airplane. It was hard to convince him that the airplane was doing exactly what the elevons were telling it to do, but the elevons were not doing what the pilot wanted them to do at very small displacements of the stick. Yes, it was stretching it a bit to read the elevon position indicators on the photo panel to less that a tenth of a degree, but it definitely could be shown through the gyro horizon and directional gyro instruments in the photo panel that the airplane was responding precisely to the small (less than 1/10 of a degree) movements of the elevons.

The author conducted ground tests to determine if the selsyn indicators in the photo panel were accurately showing elevon position. Strain gauge type sensors were installed on the elevons to record their angular position on an oscillograph recorder. The two ways of measuring elevon position were compared.

From flight tests to determine Short Period Dynamic "Longitudinal" Stability (Fig. 10) you see that the maximum rate of motion of the elevons was 8° per second. Mr. Shannon felt that photo panel instruments could not react fast enough when he applied impulses to the stick or rudder. From ground tests, however, (Fig. 11) we see that when the elevons are moving at a rate as high as 25° per second the photo panel instrument readings (the small black dots) overlay the oscillograph plot. Only when the elevons moved at 40° per second in the ground tests did the photo panel indicators lag behind for about two tenths of a second. But then they caught up and were showing true elevon position.

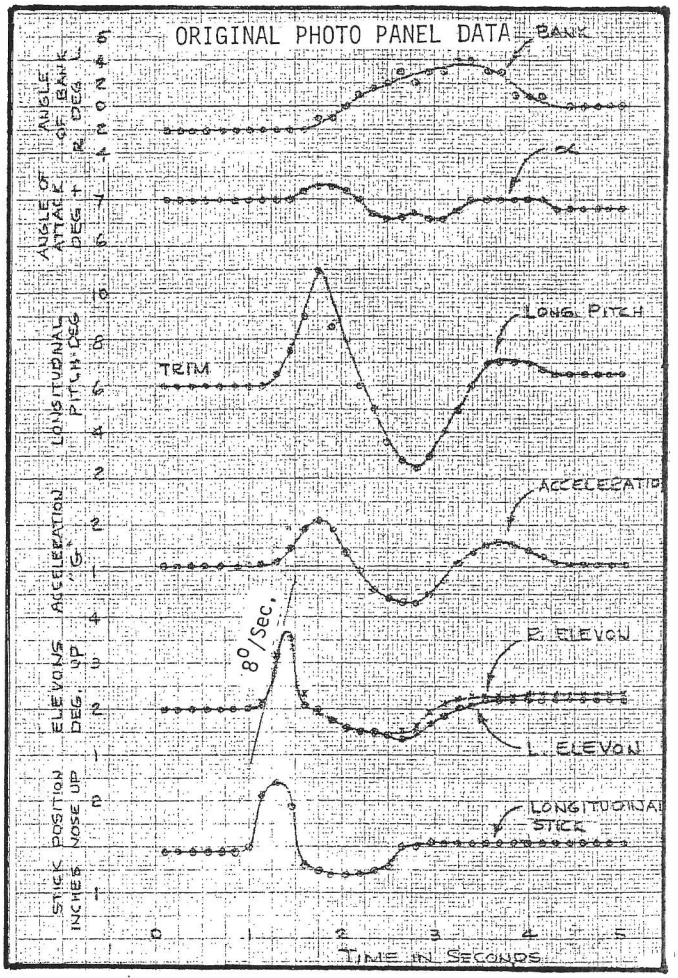

Figure 10 Dynamic Longitudinal Stability (Short Period)

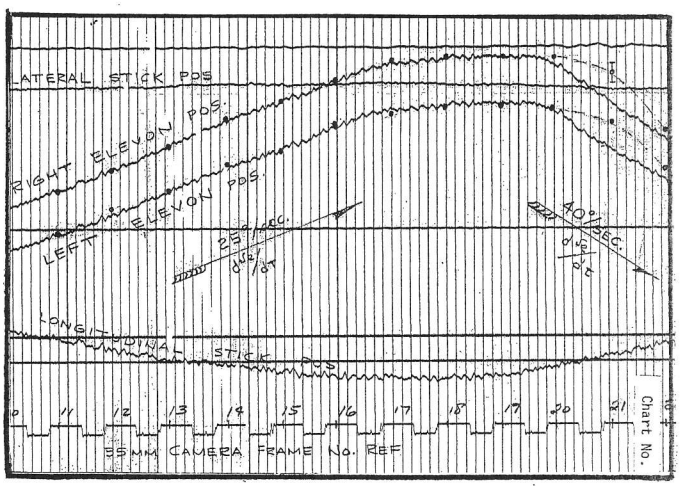

Figure 11 Ground Tests - Elevon Positions - Photo Panel Instruments vs the Oscillograph Recorder

From flight tests to determine Short Period Dynamic "Directional" Stability (Fig. 12) you see that the rate of change of side slip (yaw) taken from the photo panel was 8° per second, when a rudder kick was applied by the pilot. From the ground tests (Fig. 13) we see that for yaw angle changes of 3° and 10° per second the photo panel instrument readings (the small black dots) overlay the oscillograph plot.

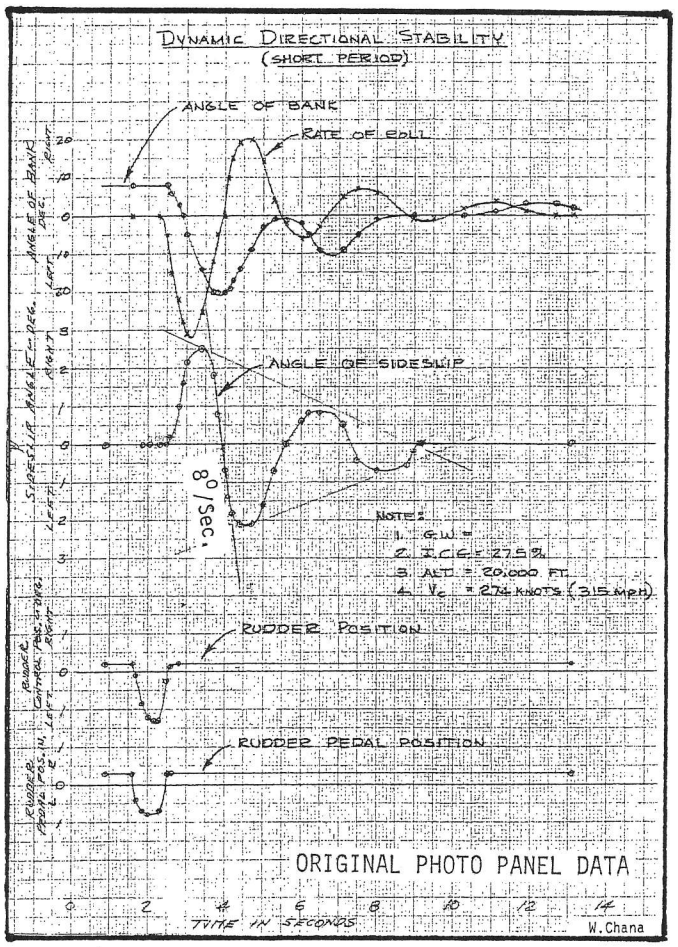

Figure 12 Dynamic Directional Stability (Short Period)

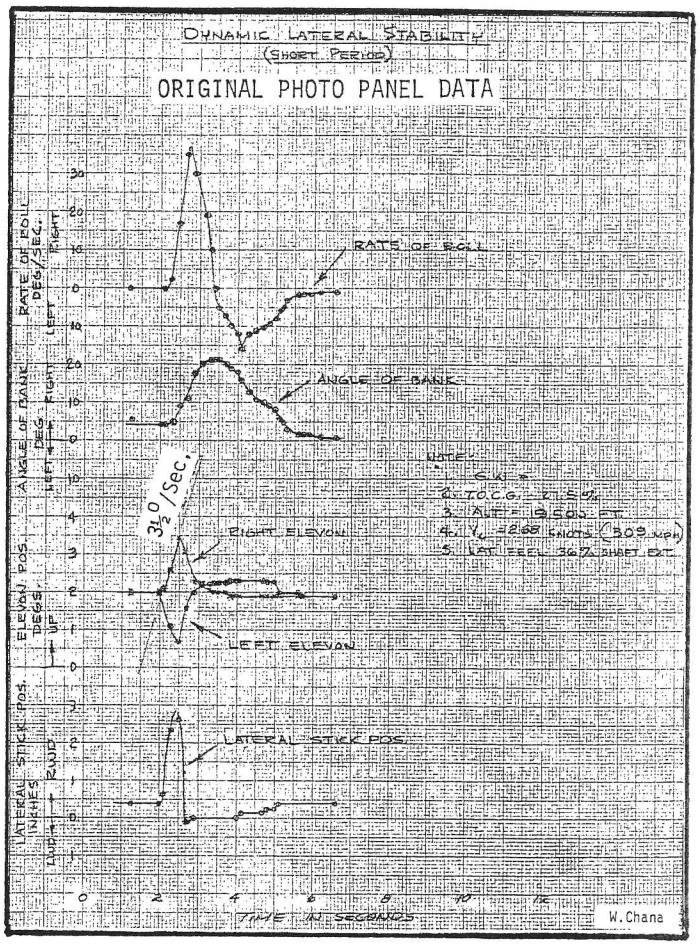

Figure 14 Dynamic Lateral Stability (Short Period)

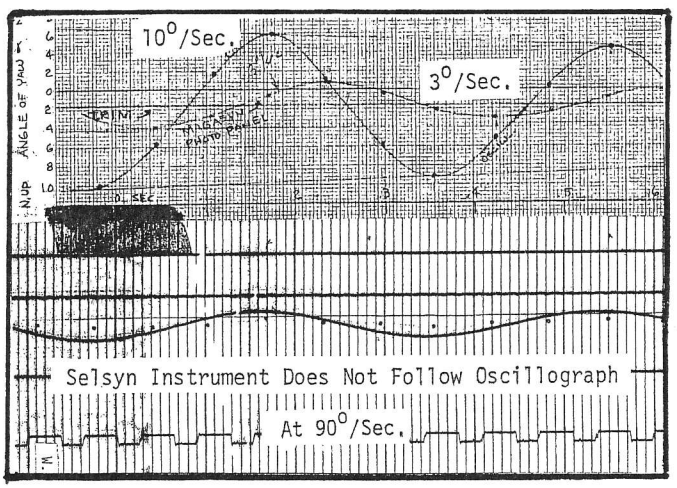

Figure 13 Ground Tests - Yaw Angle - Photo Panel Selsyn Instrument ● vs the Oscillograph Recorder ——

From flight tests to determine Short Period Dynamic "Lateral" Stability (Fig. 14) we see that a lateral impulse to the pilots stick produced only 3.5° per second movement in both elevons. Thus it was concluded that the selsyn indicators in the photo panel were showing accurate elevon positions and yaw angles for the flight tests being conducted by the Convair test pilots.

Bill Martin was Convair's second pilot on the XF-92A. Here we had another experienced bomber test pilot flying a fighter type aircraft. He also had trouble keeping the airplane from wobbling around the sky when he had his hand on the stick. Like Sam, Bill didn't think much of anyone being able to read the instruments on the photo panel to less than a tenth of a degree of elevon or rudder position.

On a series of flights flown by Martin we were starting to open up the speed envelope. When Bill got the airplane up to .75 Mach number, a loud rumble or buzz was encountered. The rumble would stop when engine thrust and airspeed were reduced. A Convair team of experts were sure that our bifurcated engine air inlet duct was the culprit. Microphones and strain gauges were installed in areas near the inlet ducts to determine rumble frequency and amplitudes. A small oscillograph recorder was installed in the aircraft to record these data. Many flights were made. Between flights, changes were made to the inlet duct and air flow spoilers were added at various locations in the duct, but the rumble or buzz was always there starting at .75 Mach. On one flight the rumble suddenly stopped while Bill was flying at high speed. Not knowing what caused the rumble to stop, Martin returned to the lake bed runway expeditiously.

Post flight inspection revealed that the VHF knife antenna immediately behind the pilot's canopy was missing. It had broken off. The attachment had become loose allowing the antenna to vibrate at the high airspeeds creating a noise that sounded and felt like turbulent airflow in the inlet duct. A new antenna was installed and securely fastened. There was no more "duct rumble".

YEAGER AND EVEREST - AIR FORCE PILOTS

Captain Chuck Yeager and Lieutenant Jim Fitzgerald were the two Air Force test pilots assigned to fly the XF-92A's Phase II Test Program. They both came to the hangar to be briefed on the airplane. Yeager had broken the sound barrier in the Bell X-1 in October 1947. Fitzgerald, like Yeager, was an experienced fighter pilot. Fitzgerald was flying the prototype T-33 from Wright Field to the Lockheed facility at Van Nuys Airport in California with a stopover at Muroc AFB. This allowed him to drop in with Yeager for a XF-92A delta briefing. The next morning, as Jim approached the Van Nuys Airport the T-33 went out of control and crashed, killing him instantly.

The Air Force immediately assigned Major Frank "Pete" Everest, another seasoned fighter pilot, to replace Fitzgerald. Sam Shannon and the author were present when Yeager made the first Air Force flight of the XF-92A on 13 October 1949. Yeager took off from the lake bed. He was up for 25 minutes but never in sight. Soon there was a small speck in the sky far out on the final approach path to the lake bed runway. Shannon said, "Well, it looks like he's coming in for a landing." As the speck got bigger it was obvious that the landing gear was not down. Sam said, "C'mon boy, get that gear down." Yeager was getting in closer and the gear was still not down. Sam said, "My God, he forgot the gear." All of us on the field were beginning to show concern.

There was Yeager heading right for us at about 200 feet off the deck and certainly not slow enough to make a landing. He went by us at a very high speed, then pulled the nose up and made several victory barrel rolls as he turned into the downwind leg and lowered the gear. He made a perfect landing. As he climbed down the ladder from the cockpit Yeager exclaimed, "Oh my goodness, just give me an airplane like this with F-86 performance and guns and I'll knock anything out of the sky." Sam walked up to Yeager and said, "Chuck, didn't you find the airplane a little sensitive to fly?" Yeager snapped back, "NO! Its OK! This is a beautiful bird! Let's get on with the test program." So that was the start of the Air Force flight test program of the world's first delta wing.

This first flight by Yeager was the first time the airplane was taken through a barrel roll. Later Yeager told us that he flew the airplane slightly out of trim so that he was always holding a few pounds of pressure both longitudinally and laterally on the stick. By doing this he eliminated one major fault in the hydraulic flight control system. He jokingly told Sam, "I never touch the stick when I fly the airplane. I just leave it alone. If I want to turn I just give the stick a push and take my hand off. I'm not worried about sensitivity."

Yeager and Everest would trade off flying the airplane. When Yeager flew the delta, Everest would fly the chase plane and vice versa. The chase pilot did not sit in on the preflight meetings held in the hangar because it took him some time to ensure that the chase plane was on the operations flight line and ready to go when he needed it.

One morning at a preflight meeting the Air Force Contracting Officer said, "Captain Yeager, I don't think you should be talking down your data during the flight. This is a secret project and we really don't know who might be listening on your radio frequency." Yeager wanted his flight test engineers to sit in the radio equipped jeep to write down every word he said so that we could later track it with the photo panel film. Yeager also wanted this done so that he could discuss the flight with his test engineers immediately after landing during the hangar post-flight meeting. Yeager's response was, "We will continue doing what we've been doing but I'll add 100 mph to the speed and 10,000 feet to the altitude and that should make any listeners happy."

Yeager released the brakes and started his takeoff roll. Everest was right there in close formation on the wing tip of the delta. Chuck came over the radio, "Climbing out at 300." Everest immediately said, "Chuck, I've got 200!" A few seconds later Yeager said, "Going through 20,000." Everest was quick to say, "Chuck, I'm going through 10,000." Yeager came back with, "Pete, if you'd get in a little closer, like a fighter pilot should, you'd get the right numbers!" Everest quips back, "If I was any closer I'd be in the cockpit with you." At this time they both burst out laughing. True fighter pilots. Two real characters. Yeager and Everest.

EXPANDING THE FLIGHT ENVELOPE

Yeager and Everest were now getting the feel of the airplane and were beginning to expand the flight envelope. The aircraft rate of roll was being measured by making stabilized barrel rolls at fixed elevon positions and at various airspeeds. Yeager was impressed with the high rates of roll capable with the delta wing. Air Force Flight Test Engineer, Dick Schmidt, assigned to the XF-92A, relates Yeager's enthusiasm. Yeager told Schmidt that he could further increase the full throw (aileron) roll rate by adding rudder in the direction of the roll. The aircraft was reacting like a dart with horizontal and vertical feathers being thrown at a dart board.

On one flight, Yeager reached the lowest possible airspeed with full up elevon. His airspeed indicator was showing 67 mph. He was at a very high angle of attack, around 30 degrees. At this high angle of attack the total head pickup on the nose boom used to measure airspeed was not picking up true total head pressure. Knowing the aircraft's weight and the maximum lift coefficient of this delta wing, it was determined later that the aircraft was at 92 mph. With full up elevon and with the jet engine at maximum thrust the aircraft was descending at about 3,000 feet per minute. Yeager had to get out of this situation in a hurry because the only way to recover was to push over

into a greater descent rate to pick up airspeed. About 10,000 feet were lost in making this slow speed full up elevon test.

The airspeed calibration (Fig. 15) is of interest. The pilot's airspeed indicator was connected to the nose boom pitot static head. You can see that if the pilot's airspeed indicator read 67 mph you would have to add 25 mph to get calibrated indicated airspeed. These add up to 92 mph which we all felt was the minimum speed ever attained by the XF-92A. The 92 mph agreed favorably with data from wind tunnel tests.

On one flight Everest started from a high altitude and with full engine thrust pointed the nose down to reach maximum airspeed. The airspeed indicator kept increasing, 400, 500, 600 mph. The airspeed needle jumped and then settled back as Everest pulled out of the dive. This was proof enough that the XF-92A had penetrated the sound barrier.

Everest had a close call in the XF-92A. Immediately after takeoff on one of his flights he observed that control system hydraulic pressure was dropping rapidly. He made a quick 180 degree turn back to the lake bed runway and landed. During the roll out, the hydraulic pressure dropped to zero and the controls froze. Post flight inspection revealed that a hydraulic leak deployed all of the hydraulic oil.

OTHER AIR FORCE TEST PILOTS

One day General Al Boyd came from Wright Field to fly the XF-92A. Boyd was Yeager's and Everest's superior officer. General Boyd got a quick cockpit check by Yeager, closed the canopy and was off into the wild blue. After landing, he stepped off the cockpit ladder and before he could say a word Mr. Shannon asked, "General, didn't you find the airplane a little sensitive laterally?" The general was quick to respond, "No, not sensitive, but if I find the guy who didn't show me where the lateral trim switch is I'll shoot him. I had to hold five pounds pressure on the stick for the whole flight and my arm is about to fall off." By holding this pressure on the stick the General, like Yeager on his flights, eliminated one major fault in the hydraulic flight control system.

The time came for the Air Force to give several of their seasoned test pilots a crack at flying the XF-92A. In early January 1950 each pilot flew the airplane for a short flight. Yeager was in radio contact from the control tower. In every case as soon as the pilot was airborne and the gear was coming up he would call Yeager and say, "Oh my goodness this thing is unstable, it's unstable." Yeager would say, " Drop the stick, drop it, don't touch it." The pilot would say, "I can't do that, it's unstable and I'm too low." Yeager would say, "I'm telling you, drop the stick." A few seconds later the pilot would yell out, "Well I'll be damned, it's as steady as a rock." He had dropped the stick.

CONCLUSION

Thus, the Convair and the Air Force Phase I and II testing of the XF-92A was concluded. The two Convair test pilots made 47 flights totalling 20 hours flight time. The two Air Force test pilots made 25 flights totalling 17 hours flight time. The airplane was shipped back to San Diego for installation of a new jet engine with afterburner, some minor modifications and an all-white paint job. It was then returned to the Edwards AFB flight test center where Yeager and Everest made several flights.

The XF-92A was then turned over to the NACA. A. Scott Crossfield was the only NACA pilot to fly it. Later, the world's first delta wing airplane was retired and it became an Air Force display airplane. To ease transportation from city to city, its wings and tail were made removable. The ship is now in the hands of the Air Force Museum at Wright Patterson Air Force Base, Ohio. Restoration of this historic airplane has been completed by the Air Force.

It is appropriate and fitting that the Convair/Air Force XF-92A be recognized as the World's First Delta Wing Airplane developed in the United States and proven through flight tests. The trio of Frank Davis, Adolph Burstein and Ralph Shick are acknowledged for their contribution in uncovering the secret of the delta wing through analysis and wind tunnel tests, proving its worth as an efficient aerodynamic shape for transonic and supersonic flight.

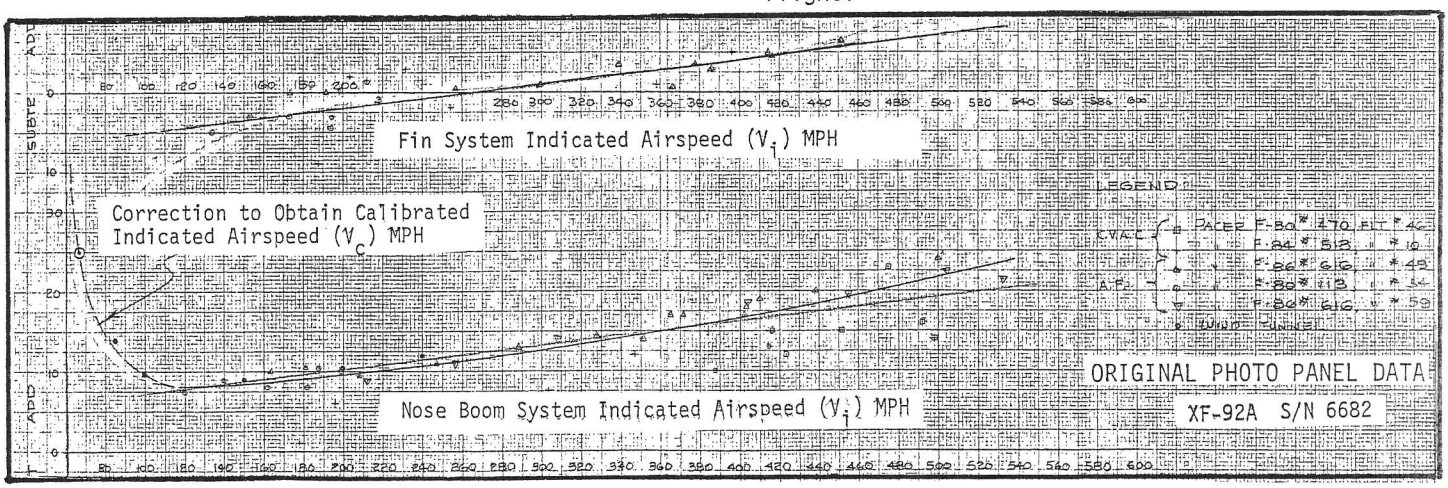
Fin System Indicated Airspeed (V_i) MPH
Correction to Obtain Calibrated Indicated Airspeed (V_c) MPH
Nose Boom System Indicated Airspeed (V_i) MPH
LEGEND
ORIGINAL PHOTO PANEL DATA
XF-92A S/N 6682

Fig. 15 Airspeed Calibration Fin & Nose Boom Position Error

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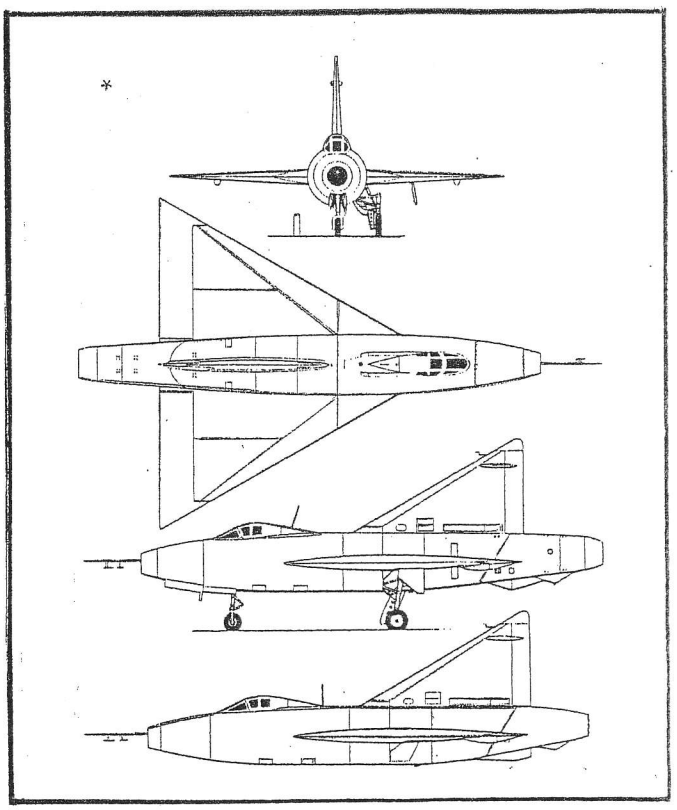


ABOUT THE AUTHOR

William F. Chana's aerospace career began in 1941 with Consolidated Aircraft Corporation in San Diego, California. As a Flight Test Engineer he played an active role in flight testing the: XPB2Y-3 four engine seaplane, XB-24 Liberator Bomber, XB-32 heavy bomber, TBY-2 Torpedo Bomber, XC-99 world's largest landplane (at the time), XF-92A world's first delta wing airplane, XFY-1 POGO world's first VTOL airplane, XF2Y-1 SeaDart world's first supersonic seaplane, Convair Turboliner first turboprop powered transport produced in the U.S., and Convair 240/340/440 commercial airliners.

In the 1950's, as an avocation, he was a partner in designing, constructing and testing (as test pilot) three small aircraft including the Wee Bee which the Newsreels and media called "The World's Smallest Airplane". The Guinness Book of World Records, in the mid 1960's, identified it as "The World's Lightest Airplane".

After twelve years in flight test, Mr. Chana became a performance and propulsion specialist in Convair's Customer Service Department working closely with all airlines and the Air Force operating Convair twin engine transports. Shortly thereafter he became Chief of Interceptor Service managing all activities related to servicing F-102 and F-106 Interceptor squadrons in the Continental United States, Alaska and Europe.

In 1960-61 he was Convair's Base Manager at Fairchild AFB, Washington, responsible for the installation and checkout of operational ATLAS missiles. Later he became Manager of ATLAS updating programs. In 1963 he was assigned as Base Manager of Convair's Sycamore Test Site responsible for ground testing and hot firings of ATLAS and CENTAUR launch vehicles.

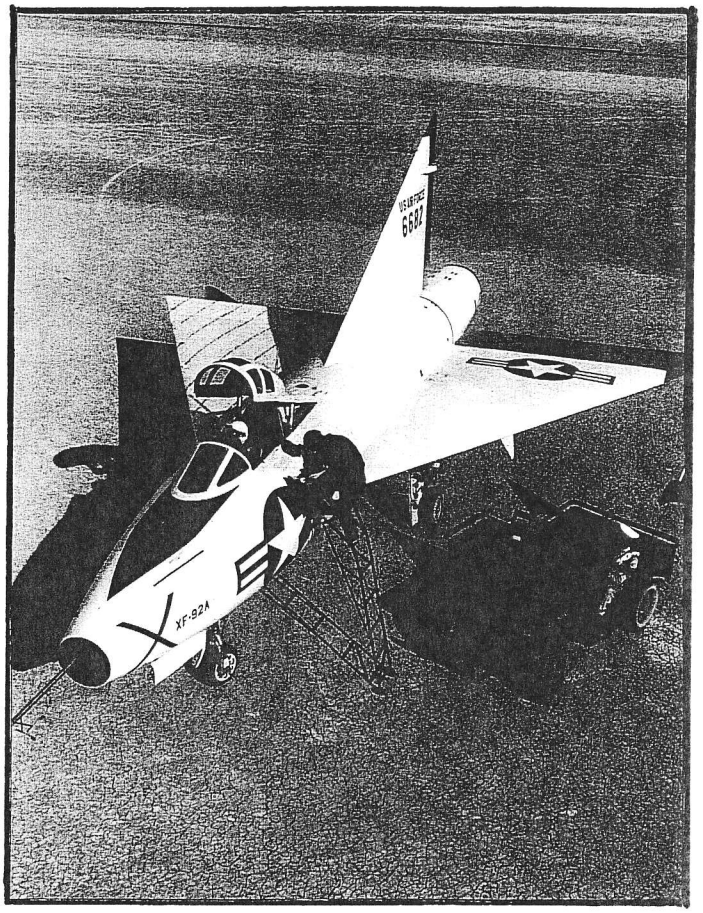
After thirty-two years with Convair he moved to Rohr Industries as Deputy Program Manager on an advanced state-of-the-art R&D triphibian airplane. This airplane incorporated a delta wing, ducted fan propulsion, all composite structure, tricycle landing gear for airports, and tri-skis for water and snow operations. The design and construction were completed. Flight tests were conducted.

In 1982 Mr. Chana formed his own consulting firm dedicated to the design and development of aircraft and aircraft modifications. For the past decade he has pursued development of the tilt wing for high speed VSTOL aircraft. The wave of the future is vertical takeoff and landing (VTOL) aircraft and Mr. Chana consults in this field of technology.

Mr. Chana has been an active member and Director of the San Diego Aerospace Museum since its opening in 1963. He served as the museum's President in 1996-98. He was awarded the 1998 A. Verville Fellowship at the Smithsonian National Air & Space Museum. He is a FELLOW in the American Institute of Aeronautics and Astronautics (AIAA) and a FELLOW in the Society of Automotive Engineers (SAE). He was the 1997 and 1999 President of the Silver Wings Fraternity in San Diego and is now a National Director. He is a member of OX-5 Pioneers, E.A.A. and Quiet Birdmen. Mr. Chana is listed in Who's Who in Aviation (1973) and Who's Who in Aviation and Aerospace (1983). He holds a Commercial Pilot and Glider license having soloed in 1945.

In 1943 he was given an award by Consolidated Vultee Aircraft Corporation for the contribution he made to aviation's progress as a survivor of a U.S. Army Air Corps XB-32 accident. In 1961 he was presented with the U.S. Air Force's Ballistic Systems Division "Commanders Award" for bringing in the first ATLAS activation program on schedule with no incidents or accidents. In 1973 he earned a Masters Degree in Technology from National University.

In his youth he was an avid model airplane builder and when a senior in high school he was the Illinois State President of the Future Craftsmen of America.



XF-92A World's First Delta Wing Airplane